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Information on the species and habitats around the coasts and sea of the British Isles

# Foliose red seaweeds on exposed lower infralittoral rock

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

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**Foliose red seaweeds on exposed lower infralittoral rock**
**Photographer:** Keith Hiscock
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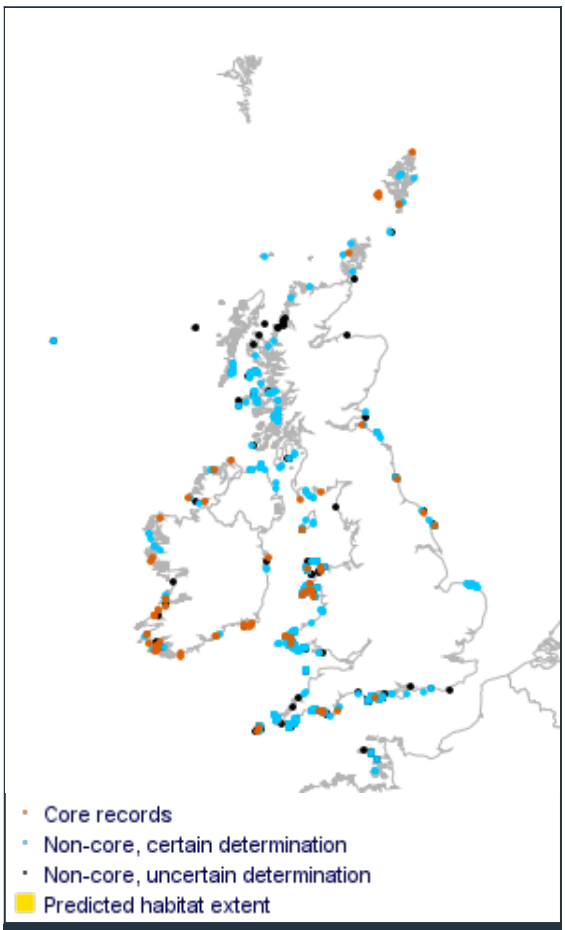


17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

**Researched by** Dr Heidi Tillin & Georgina Budd **Refereed by** This information is not refereed.

# Summary

## UK and Ireland classification

| | | |
|---|---|---|
| **EUNIS 2008** | A3.116 | Foliose red seaweeds on exposed lower infralittoral rock |
| **JNCC 2015** | IR.HIR.KFaR.FoR | Foliose red seaweeds on exposed lower infralittoral rock |
| **JNCC 2004** | IR.HIR.KFaR.FoR | Foliose red seaweeds on exposed lower infralittoral rock |
| **1997 Biotope** | IR.EIR.KFaR.FoR | Foliose red seaweeds on exposed or moderately exposed lower infralittoral rock |

## Description

A dense turf of foliose red seaweeds (including *Plocamium cartilagineum*, *Cryptopleura ramosa* and *Delesseria sanguinea*) on exposed or moderately exposed lower infralittoral rock, generally at or below the lower limit of the kelp. Most of the red seaweeds are common to the kelp zone above, while the faunal component of the biotope is made up of species that are found either in the kelp zone or the animal-dominated upper circalittoral below. The red seaweed species composition

varies considerably and at some sites a single species may dominate (particularly *Plocamium cartilagineum* or *Cryptopleura ramosa*) As well as a varied red seaweed component, this biotope may also contain occasional kelp plants and patches of the brown foliose seaweed *Dictyota dichotoma*. In some areas *Dictyota dichotoma* may occur at high densities (see EIR.FoR.Dic). Other red seaweed-dominated biotopes occur in less wave-exposed areas (MIR.PolAhn), though they are affected by sand scour and are characterized by seaweeds that are resilient to the scouring. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

## Depth range

-

## Additional information

No text entered.

## Listed By

- none -

## Further information sources

Search on:

# Habitat review

## Ecology

### Ecological and functional relationships

Foliose algae provide shelter for invertebrates, a substratum for attachment of some species and food for grazers. Dependant relationships develop and are noted below.

- The predominant environmental factor determining occurrence of this biotope is light. In the lower infralittoral there is generally insufficient light for the growth of Laminariales and substratum is dominated by foliose and encrusting red algae.
- Old stipes and midribs of *Delesseria sanguinea* become heavily encrusted with algae and epiphytic invertebrates such as bryozoa, sponges and ascidians (Maggs & Hommersand, 1993).
- The most important grazer of subtidal algae in the British Isles is the sea urchin, *Echinus esculentus*. It has demonstrated a preference for red algae. Sea urchin grazing may maintain the patchy and species rich understorey epiflora/fauna by preventing dominant species from becoming established. In wave exposed situations, sea urchins may not be able to cling on or feed in shallow depths during storms and this may favour the development of algal dominated biotopes. Also sea urchin densities vary in different parts of the coast, where numbers are low the biotope may be favoured (K. Hiscock, pers. comm.). Vost (1983) examined the effect of removing grazing *Echinus esculentus* and found that after 6-10 months the patchiness of the understorey algae had decreased and the species richness and biomass of epilithic species increased. Algae with single attachment points became more frequent in the urchin free area and the total biomass and species richness of epilithic species increased (Birkett *et al*., 1998b). *Echinus esculentus* grazing probably controls the lower limit of kelp distribution in some locations, e.g. in the Isle of Man (Jones & Kain 1967; Kain *et al*. 1975; Kain 1979).
- *Echinus esculentus* may be preyed upon by the lobster *Homarus gammarus*, and in the north, the wolf-fish *Anarhichas lupus*.
- The prosobranch mollusc *Lacuna parva* grazes extensively upon the red algae *Phyllophora crispa* and *Delesseria sanguinea* and *Phycodrys rubens*. *Phyllophora crispa* is the main substratum for spawn deposition (Ockelmann & Nielsen, 1981).
- *Corallina officinalis* may support epiphytes, including *Mesophyllum lichenoides*, *Titanoderma pustulatum*, and *Titanoderma corallinae*, the latter causing tissue damage (Irvine & Chamberlain 1994). Hay *et al.* (1987) suggested that grazing by amphipods and polychaetes caused damage to 1-20 % of the blade area of the foliose brown algae *Dictyota dichotoma*
- Other grazers include topshells, e.g. *Steromphala cineraria* and small Crustacea (amphipods and isopods) and the painted top-shell *Calliostoma zizyphinum*, which feeds upon cnidarians, as well as micro-organisms and detritus.
- Specialist predators of hydroids and bryozoans in particular include the nudibranch species such as *Janolus cristatus*, *Doto* spp. and *Onchidoris* spp. Starfish (e.g. *Asterias rubens*, *Crossaster papposus* and *Henricia* spp.) are generalist predators feeding on most epifauna, including ascidians.
- Predation does not necessarily cause mortality. For instance, *Metridium dianthus* is attacked by *Aeolidia papillosa* and by *Pycnogonum littorale*. *Alcyonium digitatum* is attacked by the nudibranch*Tritonia hombergi* and the mollusc *Simnia patula*, which also feeds upon the hydroid *Tubularia indivisa*.

- Many inhabitants of the biotope are suspension feeders and are doubtless in competition for food, although moderately strong water movement and the relatively close proximity of the highly productive kelp forests of the upper infralittoral are likely to bring a plentiful supply of food. Ninety percent of kelp production is estimated to enter the detrital food webs of coastal areas, as particulate organic matter (POM) and dissolved organic matter (DOM), supporting biotopes beyond the kelp beds (Birkett *et al*., 1998b). Suspension feeders include barnacles, ascidians such as *Clavelina lepadiformis* and *Aplidium punctum*, and anthozoans such as *Alcyonium digitatum*, *Urticina felina* and *Caryophyllia smithii* and occasional sponge crusts. Larger prey items would be taken by *Urticina felina* and *Metridium senile* (Hartnoll, 1998).

**Seasonal and longer term change**

Many of the red seaweeds in this biotope have annual fronds, which typically die back in the autumn and regenerate in the spring. Consequently a seasonal change occurs in the seaweed cover, which is substantially reduced over the winter and becomes most dense between April to September. For example, the perennial *Delesseria sanguinea* exhibits a strong seasonal pattern of growth and reproduction. New blades appear in February and grow to full size by May -June becoming increasing battered or torn and the lamina are reduced to midribs by December (Maggs & Hommersand, 1993). Blade weight is maximal in midsummer, growth dropping in June and July and becoming zero in August (Kain, 1987). Several species of bryozoans and hydroids demonstrate seasonal cycles of growth in spring/summer and regression (die back) in late autumn/winter, overwintering as dormant stages or juvenile stages (see Ryland, 1976; Gili & Hughes, 1995; Hayward & Ryland, 1998). For example, the fronds of *Bugula* species are ephemeral, surviving about 3-4 months but producing two frond generations in summer before dying back in winter, although, the holdfasts are probably perennial (Eggleston, 1972a; Dyrynda & Ryland, 1982). The hydroid *Tubularia indivisa* that may occasionally occur in the biotope is an annual, dying back in winter (Fish & Fish, 1996), while the uprights of *Nemertesia antennina* die back after 4-5 months and exhibit three generations per year (spring, summer and winter) (see reviews; Hughes, 1977; Hayward & Ryland, 1998; Hartnoll, 1998). Many of the bryozoans and hydroid species are opportunists (e.g. *Bugulina flabellata*) adapted to rapid growth and reproduction (r-selected), taking advantage of the spring/summer phytoplankton bloom and more favourable (less stormy) conditions (Dyrynda & Ryland, 1982; Gili & Hughes, 1995). Some species such as the ascidians *Ciona intestinalis* and *Clavellina lepadiformis* are effectively annual (Hartnoll, 1998). Therefore, the biotope is likely to demonstrate seasonal changes in the abundance or cover of both algae and fauna. Winter spawning species such as *Alcyonium digitatum* may take advantage of the available space for colonization.

**Habitat structure and complexity**

- The biotope occurs over bedrock surfaces and large boulders, the nature of which provide a variety of surface aspects. The species composition probably varies with depth from the upper limit of the lower infralittoral towards the circalittoral. For example, foliose and encrusting red algae probably out-compete the faunal turf species on tops of bedrock ridges, but decline on vertical surfaces and with depth.
- The algal and faunal turf provides interstices and refuges for a variety of small organisms such as nemerteans, polychaetes, amphipods, and prosobranchs.

  Larger mobile species include decapod crustaceans such as shrimps, crabs, hermit crabs, lobsters, sea urchins, starfish and fish. Such species are not highly faithful to the biotope,

but probably utilize available rock ledges and crevices for shelter.

**Productivity**

Specific information concerning the biotope was not found. Foliose and encrusting red algae are primary producers in the EIR.FoR biotope, the biomass of which will enter the food chain indirectly in the form of detritus, algal spores and abraded algal particulates, or directly as food for grazing gastropods, sea urchins or fish. The biotope is likely, however, to receive more particulate and dissolved organic matter (POM & DOM) from kelp biotopes in the upper infralittoral. Kelps are the major primary producers in UK marine coastal waters producing nearly 75 % of the net carbon fixed annually on the shoreline of the coastal euphotic zone (Birkett *et al.*, 1998b). Kelp plants produce 2.7 times their standing biomass per year. Refer to EIR.LhypFa and EIR.LhyphR.

**Recruitment processes**

Recruitment into the biotope occurs as a result of spore or larval settlement and by migration. Information on some of the characterizing species is given below:

- The onset of sexual reproduction in *Delesseria sanguinea* is stimulated by day length, *Delesseria sanguinea* is a short-day plant sensitive to a night-break (Kain, 1991; Kain, 1996]. Kain (1987) suggested that the southern limit of *Delesseria sanguinea* may be determined by winter temperatures. Studies in Roscoff and Helgoland support that observation; new blades formed in April - June at Roscoff, males plants in October - December, cystocarps and tetrasporangia in October - December, the last cystocarps found in April. Recruitment of *Delesseria sanguinea* occurred between February and April/June in both Roscoff and Helgoland (Molenaar & Breeman, 1997).
- *Corallina officinalis* produces spores over a protracted period and can colonize artificial substratum within one week in the intertidal (Harlin & Lindbergh, 1977; Littler & Kauker, 1984).
- Sea urchins most likely migrate into the biotope rather than settle directly there. However, maximum spawning of *Echinus esculentus* occurs in spring although individuals may spawn over a protracted period. Gonad weight is maximal in February / March in the English Channel (Comely & Ansell, 1989) but decreases during spawning in spring and then increases again through summer and winter until the next spawning; there is no resting phase. Spawning occurs just before the seasonal rise in temperature in temperate zones but is probably not triggered by rising temperature (Bishop, 1985). Planktonic development is complex and takes between 45 -60 days in captivity (MacBride, 1914). Recruitment is sporadic or variable depending on locality.
- Hydroids are often the first organisms to colonize available space in settlement experiments (Gili & Hughes, 1995). For instance, *Nemertesia antennina* releases planulae on mucus threads, that increase potential dispersal to 5 -50m, depending on currents and turbulence (Hughes, 1977). Most species of hydroid in temperate waters grow rapidly and reproduce in spring and summer. Few species of hydroids have specific substratum requirements and many are generalists. Hydroids are also capable of asexual reproduction and many species produce dormant, resting stages, that are very resistant of environmental perturbation (Gili & Hughes, 1995).
- Sponges may proliferate both asexually and sexually. A sponge can regenerate from a broken fragment, produce buds either internally or externally or release clusters of cells known as gemmules which develop into a new sponge. However, some sponges appear to be long-lived, slow growing and recruit infrequently. For instance, monitoring studies at

Lundy revealed extremely slow growth and no recruitment of *Axinella dissimilis* (Hiscock, 1994).

- Anthozoans, such as *Alcyonium digitatum* and *Urticina felina* are long lived with potentially highly dispersive pelagic larvae and are relatively widespread. They are not restricted to this biotope and would probably be able to recruit rapidly (refer to full *MarLIN* reviews). Similarly, *Metridium senile* has a long lived, dispersive planktonic planula larva. However, it is also capable of reproducing asexually by budding form the base, and colonizes space aggressively, forming clumps (Sebens, 1985; Hartnoll, 1998). Juveniles are susceptible to predation by sea urchins or overgrowth by ascidians (Sebens, 1985; 1986).
- Development of *Lacuna parva* is direct and takes about two months at 10-11 °C . After copulation females may produce fertilized eggs for two to three months. The species has an annual life cycle with mating prior to the production of spawn between March and June, death of adults occurs throughout May and June, the main hatching of new recruits occurs in June and July (Ockelman & Nielsen, 1981).
- Mobile fauna, crabs, fish and starfish, will probably recruit from the surrounding area either by migration or from planktonic larvae, as the community develops and food, niches and refuges become available, .

**Time for community to reach maturity**

It is likely that Rhodophyceae could recolonize an area from adjacent populations within a short period of time in ideal conditions but that recolonization from distant populations would probably take longer.

Many of the Rhodophyta e.g. *Delesseria sanguinea*, *Plocamium cartilagineum*, *Dilsea carnosa* and *Corallina officinalis* are perennial species that may persist for several years. For instance, Dickinson (1963) suggested a lifespan of 5-6 years for *Delesseria sanguinea*. However, Kain (1984) estimated that 1 in 20 specimens of *Delesseria sanguinea* may attain 9 - 16 years of age. Kain (1975) examined recolonization of cleared concrete blocks in a subtidal kelp forest. Red algae colonized blocks within 26 weeks in the shallow subtidal (0.8m) and 33 weeks at 4.4m. *Delesseria sanguinea* was noted within 41 weeks (8 months) at 4.4m in one group of blocks and within 56-59 days after block clearance in another group of blocks. This recolonization occurred during winter months following spore release and settlement, but not in subsequent samples (Kain, 1975). This suggests that colonization of *Delesseria sanguinea* in new areas is directly dependent on spore availability. Rhodophyceae have non flagellate, and non-motile spores that stick on contact with the substratum. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition. However, red algae produce large numbers of spores that may settle close to the adult especially where currents are reduced by an algal turf or in kelp forests.
Many of the sessile fauna present in the EIR.FoR biotope such as alcyonarians, ascidians and sponges, are present in the communities described by Sebens (1985) which were considered to be dynamic and fast growing. Smaller associated mobile species such as polychaetes and prosobranchs have planktonic larvae and would most likely colonize after a year. Large mobile species such as sea urchins, starfish and crabs would migrate into the area rapidly. The community may therefore take probably two or three years to reach maturity, but competitive interactions and the arrival of slower colonizing species could mean that dynamic stability is not achieved for several years.

**Additional information**

No text entered

## Preferences & Distribution

### Habitat preferences

| | |
|---|---|
| **Depth Range** | |
| Water clarity preferences | |
| **Limiting Nutrients** | Nitrogen (nitrates) |
| **Salinity preferences** | |
| **Physiographic preferences** | |
| **Biological zone preferences** | |
| **Substratum/habitat preferences** | |
| **Tidal strength preferences** | |
| **Wave exposure preferences** | |
| **Other preferences** | Wave exposure |

### Additional Information

- Nitrogen is the primary resource that limits seaweed growth and consequently variations in seaweed growth should parallel variations in nitrogen supply (Lobban & Harrison, 1997).
- in wave exposed situations the sea urchin, *Echinus esculentus*, may experience difficulty maintaining contact with the rock whilst grazing in shallow waters owing to turbulence caused by wave action. Such disturbance may favour the development of this algal dominated biotope.

## Species composition

### Species found especially in this biotope

### Rare or scarce species associated with this biotope

-

### Additional information

No text entered

# Sensitivity review

## Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species is taken from Connor *et al*., (2004). This biotope is found on steep wave-surged entrances to gullies and caves and on unstable boulders in the entrance to caves and gullies. The rock may be abraded by the movement of the boulders and cobbles in heavy surge and tends to be dominated by dense foliose red seaweeds that grow rapidly in the calmer summer months. Beneath the foliose seaweeds the rock surface is typically covered with coralline crusts, which are longer-lived, and tolerant of abrasion. The flora of this biotope is relatively varied, depending upon the amount of light and degree of abrasion or rock mobility with red seaweeds such as *Cryptopleura ramosa*, *Plocamium cartilagineum*, *Odonthalia dentata*, *Callophyllis laciniata*, *Phycodrys rubens*, *Hypoglossum hypoglossoides*, *Phyllophora crispa* and *Corallina officinalis*. The brown seaweed *Dictyota dichotoma* also occurs in these conditions, since it is tolerant of some sand scour. As the key characterizing species that define and structure the biotope, evidence for the sensitivity of these species is considered in the sensitivity assessments.

During the summer months small fast-growing kelp plants can arise in this biotope, although the mobility of the substratum prevents the kelp from forming a kelp forest. Dense swathes of very young kelp such as *Laminaria hyperborea* are, however, not uncommon, these species are not considered to characterize the biotope and are not considered within the assessments. The faunal community consist of the anemone *Urticina felina*, the sponge *Halichondria panicea* and the ascidian *Dendrodoa grossularia*, the sensitivity of these species is considered generally within the sensitivity assessments. More mobile fauna include the echinoderms *Asterias rubens* and *Echinus esculentus*, the top shell *Gibbula cineraria* and the crab *Cancer pagurus*. The sensitivity of *Echinus esculentus* and the top shell are described generally in the sensitivity assessments as these species can structure biotopes by grazing on the algal turf and removing epifaunal recruits (Turner & Todd, 1991). Where grazing levels are high only coralline crusts may be present as the growing meristem is sheltered under the coralline surface and therefore resistant to grazing (Littler & Kitching, 1996).

Water movement and abrasion resulting from sediment instability are key factors structuring the biotope and significant alteration to these is likely to change the character of the biotope. Where pressures may alter these factors this is identified and discussed within the sensitivity assessments.

## Resilience and recovery rates of habitat

The red algae (Rhodophyta) and the brown algae *Dictyota dichotoma* that characterize this biotope have complex life histories and exhibit distinct morphological stages over the reproductive life history. Alternation occurs between asexual spore producing stages (tetrasporophytes) and male and female plants producing sexually (gametophytes). Life history stages can be morphologically different or very similar. Many red algae, including the characterizing species *Plocamium cartilagineum*, have prostrate creeping bases that produce erect branches whereas other species present in the biotope such as *Dictyopteris membranacea*, *Callophyllis laciniata*, *Heterosiphonia plumosa* the thallus or fronds arise from a small discoid holdfasts. The tetrasporophyte of *Bonnemaisonia asparagoides* is perennial and occurs as a crustose base that grows laterally, whereas the gametophyte is annual.

The spores of red algae are non-motile (Norton, 1992) and therefore entirely reliant on the

hydrographic regime for dispersal. Norton (1992) reviewed dispersal by macroalgae and concluded that dispersal potential is highly variable, recruitment usually occurs on a much more local scale, typically within 10 m of the parent plant. Hence, it is expected that the red algal turf would normally rely on recruitment from local individuals and that recovery of populations via spore settlement, where adults are removed, would be protracted.

Littler & Kauker (1984) suggest that crustose bases are an adaptation to resist grazing and desiccation whereas the fronds are adapted for higher primary productivity and reproduction. The basal crusts of *Corallina officinalis* are tougher than the upright fronds (requiring a pressure of 94 g/mm$^2$ to penetrate, compared to 43 g/mm$^2$ respectively). Regeneration of the basal crusts provides a more rapid route to recovery than recolonization. Experiments in the intertidal in southern California found that areas of *Corallina officinalis* scraped back to crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1984). Resistant crustose bases therefore enable the turf of red algae and the crustose corallines to withstand and recover from physical disturbance and scour while preventing the establishment of other species (Mathieson & Burns, 1975; Dudgeon & Johnson, 1992). Where these remain after an impact they provide a significant recovery mechanism. Species without crustose bases may also reproduce vegetatively, for example *Dictyota dichotoma* can reproduce vegetatively by fragmentation (Tronholm *et al*., 2010). *Heterosiphonia plumosa*, can also regrow from fragments (Boney, 1975).

Some species found in this biotope, such as *Plocamium cartilagineum*, *Bonnemaisonia asparagoides* and *Delesseria sanguinea* exhibit annual growth and die back, where growth is removed annually by abrasion or water action from winter storms reducing the biomass. Regrowth from holdfasts or crustose bases occurs in the spring (Kain, 1982, 1984, 1987; Maggs & Hommersand, 1993). Some temporal variation in abundance and biomass is therefore normal within this biotope. Macroalgae characterizing the biotope are either species with strategies to resist disturbance e.g. growing back from more resistant crustose bases or short-lived species that can reproduce annually and maintain presence via germlings. *Dictyota dichotoma*, for example, is an annual plant in North Carolina (where young germlings overwinter) and plants reach maturity and die back (Richardson, 1979).

Seasonality of reproduction varies between the red algal species within the site (Kain, 1982), so that timing of impacts will coincide with different phases of reproduction within species and may alter short-term recovery trajectories with effects on composition. In the Isle of Man, approximately 90 % of *Plocamium cartilagineum*, and *Cryptopleura ramosa* plants were fertile in late summer but less than 10% in spring, although some fertile plants were always present. The encrusting coralline *Cruoria pellita* showed little seasonality (Kain, 1982). Kain (1975) examined recolonization of cleared concrete blocks in a subtidal kelp forest. Red algae colonized blocks within 26 weeks in the shallow subtidal (0.8 m) and 33 weeks at 4.4 m. *Delesseria sanguinea* was noted within 41 weeks (8 months) at 4.4 m in one group of blocks and within 56-59 days in blocks cleared at two monthly intervals during winter months, but not in subsequent samples (Kain, 1975). This suggests that *Delesseria sanguinea* can recolonize areas, but is directly dependent on its reproductive season and spore availability. Rhodophyceae have non flagellate, and non-motile spores that stick on contact with the substratum. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition. However, red algae produce large numbers of spores that may settle close to the adult especially where currents are reduced by an algal turf or in kelp forests. It is likely that this species could recolonize an area from adjacent populations within a short period of time in ideal conditions but that recolonization from distant populations would probably take longer.

Although ubiquitous in marine coastal systems little is understood about the taxonomy, biology and ecology of the characterizing crustose corallines (Littler & Littler, 2013). Coralline crust is a generic term that in UK biotopes refers to nongeniculate (crustose) species from the family Corallinacea that could include *Lithothamnion* spp. and *Phymatolithon* spp. and *Lithophyllum incrustans* which is noted to form thick crusts in tidepools, especially in the south west (Adey & Adey, 1973) Due to the lack of evidence for species the assessments are generic, although species specific information is presented where available. A number of papers by Edyvean & Ford (1984a & b; 1986; 1987) describe aspects of reproduction and growth of encrusting coralline, *Lithophyllum incrustans*. Studies by Edyvean & Forde (1987) in populations of *Lithophyllum incrustans* in Pembroke south-west Wales suggest that reproduction occurs on average early in the third year. Reproduction may be sexual or asexual. Populations release spores throughout the year but abundance varies seasonally, with the populations studied in Cullercoats Bay, and Lannacombe Bay (North East and South West England, respectively) producing less spores in the summer. Spore release is initiated by changes in temperature or salinity (see relevant pressure information) at low tide so that spore dispersal is restricted to within the tide pool enhancing local recruitment. Within subtidal biotopes this is not possible and recruitment success may be altered (although this may be compensated by avoidance of desiccation). Spore survival is extremely low with only a tiny proportion of spores eventually recruiting to the adult population (Edyvean & Ford, 1986). The spores are released from structures on the surface called conceptacles, these are formed annually and are subsequently buried by a new layer of growth. Plants can be aged by counting the number of layers of conceptacles. Edyvean & Ford (1984) found that the age structure of populations sampled from Orkney (Scotland), Berwick (northern England) and Devon (England) were similarMortality seemed highest in younger year classes with surviving individuals after the age of 10 years appearing relatively long-lived (up to 30 years). In St Mary's Northumberland, the population was dominated by the age 6-7 year classes (Edyvean & Ford, 1984). Growth rates were highest in young plants measured at Pembroke (south-west Wales) with an approximate increase in diameter of plants of 24 mm in year class 0 and 155 mm in year 1 and slowing towards an annual average horizontal growth rate of 3mm/year (Edyvean & Ford, 1987).

Some repair of damaged encrusting coralline occurs through vegetative growth. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. Recolonization by propagules is an important recovery mechanism; Airoldi (2000) observed that encrusting coralline algae recruited rapidly on to experimentally cleared subtidal rock surfaces in the Mediterranean Sea, reaching up to 68% cover in 2 months.

As a group, echinoderms are highly fecund; producing long lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependent on environmental conditions such as temperature, water quality and food availability. Recovery of populations may occur through repair of non-lethal damage, adult migration into impacted areas or larval colonization. Lewis and Nichols (1979) found that adults were able to colonize an artificial reef in small numbers within 3 months and the population steadily grew over the following year. Similarly, Nichols (1981; 1984) reported that a site where all sea urchins were removed in 1978 had returned by a subsequent survey in 1979 (although no abundance was given). Recruitment of urchins is sporadic or annual, depending on locality and factors affecting larval pre-settlement and post-settlement survival. For example, in the heart urchin *Echinocardium cordatum* recruitment only occurred in 3 years out of a 10 year period (Buchanan, 1967). Millport populations of *Echinus esculentus* showed annual recruitment, whereas few recruits were found in Plymouth populations during Nichols studies between 1980

and 1981 (Nichols, 1984). Bishop and Earll (1984) suggested that the population of *Echinus esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years. Also, *Echinus* is slow to mature and it would take up to 8 years for adult biomass to be restored (MES, 2010). It is possible for *Echinus* to recolonize areas from which it is lost quickly by migration, where there is a large resident population in the surrounding area, such as on rocky or hard substrata. However, recruitment is more variable, annual in some cases or prolonged in others. Therefore, as *Echinus esculentus* is widespread and abundant around the coasts of the UK, a local population is likely to recover via migration from the surrounding area, and a resilience of 'High' (<2 years) is suggested, however it should be noted that in isolated areas dependent on recruitment alone, resilience would likely be 'Medium' (2-10 years). In contrast, *Gibbula cineraria*, another grazer within the biotope, is a fast growing species with a short-lifespan (Schöne *et al*., 2007) and pelagic dispersal stages (Underwood, 1972) and is considered to recover quickly (resilience is 'High' through migration from adjacent habitats and larval recolonization from any level of impact.

**Resilience assessment**. Where resistance is 'High' resilience is assessed as 'High' by default. Where resistance is 'Medium' then recovery is considered to be 'High' (<2 years) based on recolonization from the remaining population and vegetative growth and spread of perennial algae. Where resistance is 'Low' but crustose bases of red algae and parts of the crustose corallines remain then recovery is also assessed as 'High'. However where resistance is 'Low' or 'None' and holdfasts are likely to be removed then resilience is assessed as 'Medium' (2-10 years).

**NB**: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

## Hydrological Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Temperature increase (local)** | High<br>Q: High A: Medium C: Medium | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Medium C: Medium |

The key characterizing red algal species found in this biotope have a range of geographic distributions with some having a 'southern distribution' with their range encompassing warmer waters and others having a 'northern' distribution. Temperature tolerances are therefore likely to vary between species so that long-term changes in temperature have the potential to shift the species composition of this biotope to one more suited to the prevailing thermal regime. This biotope occurs in the subtidal and is therefore protected from exposure to air so that the thermal regime is more stable and desiccation is not a factor. Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support the sensitivity assessment. Populations can acclimate to prevailing conditions (Davison, 1991; Lohrmann *et al*.,

2004) which can alter tolerance thresholds and care should therefore be used when interpreting reported tolerances.

A number of the characterizing species found in the biotope such as *Dictyopteris membranacea*; *Heterosiphonia plumosa*, *Cryptopleura ramosa*, *Plocamiujm cartilagineum* and *Lithophyllum incrustans* are close to the northern edge of their reported distribution range in the UK (Kain, 1982, Guiry & Guiry, 2015). *Cryptopleura ramosa*, for example, is more common on southern shores of the UK (see MarLIN) and its distribution appears to be southern with worldwide records but none, from Canada, Scandinavia, Russia the Arctic or Antarctic (Guiry & Guiry, 2015) suggesting that it is likely to tolerate increased temperatures more successfully than decreased. The brown alga *Dictyota dichotoma* is also considered to be a warm-temperate species and is found throughout the NE Atlantic and Bermuda with the northern range extending to southern Norway and North Carolina (Richardson, 1979; Hoek, 1982; Tronholm *et al*., 2010). Based on the geographic range these species are considered more likely to tolerate chronic and acute increases in temperature at the pressure benchmark and a long-term change exceeding the pressure benchmark may increase habitat suitability. Tolerances within the southern group of red algae may vary, *Cryptopleura ramosa*, for example, is capable of surviving at 27 °C, while another characterizing species *Plocamium cartilagineum*, died within 12 hours in seawater at 27 °C (Gessner, 1970). (It should be noted that this temperature increase exceeds that of the benchmark level).

There is some evidence to suggest that blade growth in *Delesseria sanguinea* is delayed until ambient sea temperatures fall below 13 °C, although blade growth is likely to be intrinsically linked to gametangia development (see Kain, 1987). *Delesseria sanguinea* is tolerant of 23 °C for a week (Lüning, 1984) but dies rapidly at 25 °C. Rietema (1993) reported differences in temperature tolerance between North Sea and Baltic specimens. North Sea and Baltic specimens grew between 0-20 °C, survived at 23 °C but died at 25 °C rapidly (Rietema, 1993). Lüning (1990) reports optimal growth in *Delesseria sanguinea* between 10 - 15 °C and optimal photosynthesis at 20 °C. However, the upper limit of temperature tolerance is reduced by lowered salinity in Baltic specimens (Kinne, 1970; Kain & Norton, 1990). At low salinity photosynthesis is restricted to a narrow range of temperatures in adult thalli whereas juvenile thalli have a wider response range (Lobban & Harrison, 1997; fig 6.27). It is likely therefore that within the subtidal an increase in temperature of 2 °C in the long-term will have limited effect on survival, although it may affect initiation of new growth at the southern limits of the population. An increase of 5 °C in the short-term may affect survival if the ambient temperature is increased above 23 °C.

Increases in temperature at the pressure benchmark may impact the associated fauna. *Echinus esculentus* was recorded at temperatures between 0 -18 °C in the Limfjord, Denmark (Ursin, 1960). Bishop (1985) noted that gametogenesis proceeded at temperatures between 11 - 19 °C although continued exposure to 19 °C destroyed synchronicity of gametogenesis between individuals. Embryos and larvae developed abnormally after up to 24 hr at 15 °C (Tyler & Young, 1998) but normally at the other temperatures tested (4, 7 and 11 °C at 1 atmosphere). Bishop (1985) suggested that this species cannot tolerate high temperatures for prolonged periods due to increased respiration rate and resultant metabolic stress. *Echinus esculentus* is likely to have higher resistance to chronic long-term temperature change at the pressure benchmark but would probably be more intolerant of a short-term acute change (e.g. 5 °C for 1 week) in temperature. The impact of a chronic change may be exacerbated or mitigated by the timing of the exposure with changes in summer having the potential to exceed thermal tolerances, although winter increases may also be stressful where the species has acclimated to cooler waters. Effects on larval supply and recruitment may also result from chronic and acute changes depending on site-specific temperatures.

**Sensitivity assessment.** The associated red algae and *Dictyota dichotoma* are considered likely to be tolerant of an acute or chronic change at the pressure benchmark, with most species, particularly those with a southern distribution, able to tolerate an acute increase in temperature greater than the pressure benchmark (Gessner, 1970). For the grazing species *Echinus esculentus* however, increases in temperature could disrupt reproduction. The effects would depend on the magnitude, duration and footprint of the activities that result in this pressure. Biotope resistance is assessed as 'High' based on the red algae and resilience as 'High' (by default). This biotope is therefore considered to be 'Not sensitive' at the pressure benchmark. Sensitivity to longer-term, broad-scale perturbations such as increased temperatures from climate change could however be greater, based on degree of change, with direct effects on the composition of the red algae present or indirect effects arising from reduced grazing where reproduction success of *Echinus esculentus* is impacted.

| | | | |
|---|---|---|---|
| **Temperature decrease (local)** | High<br>Q: High A: Medium C: Medium | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Low C: Medium |

The key characterizing red algal species found in this biotope have a range of geographic distributions with some having a 'southern distribution' with their range encompassing warmer waters and others having a 'northern' distribution. Temperature tolerances are therefore likely to vary between species so that long-term changes in temperature have the potential to shift the species composition of this biotope to one more suited to the prevailing thermal regime. Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support the sensitivity assessment. Populations can acclimate to prevailing conditions (Davison, 1991; Lohrmann *et al*., 2004) which can alter tolerance thresholds. During experimental attempts to adapt red algae to cold by maintaining them at -1°C to + 1°C for several months, a drop in the lethal temperature tolerance of *Delesseria sanguinea* and a few other species was detected, in the order of 1 to 2°C (Gessner, 1970). Care should therefore be used when interpreting reported tolerances.

The brown alga *Dictyota dichotoma* is considered to be a warm-temperate species and is found throughout the NE Atlantic and Bermuda with the northern range extending to southern Norway and North Carolina (Richardson, 1979; Van den Hoek, 1982; Tronholm *et al*., 2010) and may be sensitive to decreased temperatures. Richardson (1979) demonstrated that the young germling stage of *Dictyota dichotoma* can overwinter in North Carolina at the northern edge of its distribution where winter water temperatures are less than 10 °C, providing a survival strategy. A number of the characterizing species found in the biotope such as *Dictyopteris membranacea*, *Heterosiphonia plumosa*, *Plocamium cartilagineum*, *Cryptopleura ramosa*, and *Lithophyllum incrustans* are also close to the northern edge of their reported distribution range in the UK (Kain, 1982, Guiry & Guiry, 2015). *Cryptopleura ramosa*, for example, is more common on southern shores of the UK (see MarLIN) and its distribution appears to be southern with worldwide records but none, from Canada, Scandinavia, Russia the Arctic or Antarctic (Guiry & Guiry, 2015) suggesting that it is likely to tolerate increased temperatures more successfully than decreased. Edyvean & Forde (1984b) suggest that populations of the crustose coralline, *Lithophyllum incrustans*, are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning. However, no information on thresholds was provided (Edyean & Ford, 1984b). Tolerance of reductions in temperature will vary within this group. In experiments *Cryptopleura ramosa* were partially or completely killed at 5 °C. Other species had a greater cold tolerance with *Plocamium cartilagineum* surviving at -2 °C (Gessner, 1970).

There is some evidence to suggest that blade growth in *Delesseria sanguinea* is delayed until ambient sea temperatures fall below 13 °C, although blade growth is likely to be intrinsically linked to gametangia development (see Kain, 1987). Rietema (1993) reported temperature differences in temperature tolerance between North Sea and Baltic specimens. North Sea and Baltic specimens grew between 0-20 °C, survived at 23 °C but died at 25 °C rapidly (Rietema, 1993). Lüning (1990) reports optimal growth in *Delesseria sanguinea* between 10 - 15 °C and optimal photosynthesis at 20 °C. However, the upper limit of temperature tolerance is reduced by lowered salinity in Baltic specimens (Kinne, 1970; Kain & Norton, 1990). At low salinity photosynthesis is restricted to a narrow range of temperatures in adult thalli whereas juvenile thalli have a wider response range (Lobban & Harrison, 1997; fig 6.27). It is therefore likely that an increase in temperature of 2 °C within the subtidal in the long-term will have limited effect on survival, although it may affect initiation of new growth at the southern limits of the population. An increase of 5 °C in the short-term may affect survival if the ambient temperature is increased above 23 °C. Species that occur north and south of the UK such as *Bonnemaisonia asparagoides* (Rueness & Åsen, 1982) are considered to be eurythermal and tolerant of a range of temperatures.

*Echinus esculentus* was recorded at temperatures between 0 -18°C in the Limfjord, Denmark (Ursin, 1960). Embryos and larvae developed abnormally after up to 24 hr at 15 °C but normally at the other temperatures tested (4, 7 and 11 °C at 1 atmosphere) (Tyler & Young, 1998). This species is therefore considered to be unaffected by decreases in temperature at the pressure benchmark

**Sensitivity assessment.** The characterizing red algae and *Dictyota dichotoma* are considered to be tolerant of an acute or chronic decrease in temperature at the pressure benchmark, with some species, particularly those with a northern distribution, able to tolerate an acute decrease in temperature greater than the pressure benchmark (Gessner, 1970). Changes in temperature may result in some shifts in community structure where thermal tolerances are exceeded `and more sensitive species die but these changes are not considered to alter the overall character of the biotope. Resistance is therefore assessed as 'High' and resilience as 'High' (by default) based on the red algae. This biotope is therefore considered to be 'Not sensitive' at the pressure benchmark

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| | | | |
|---|---|---|---|
| **Salinity increase (local)** | Low<br>Q: Low A: NR C: NR | Medium<br>Q: High A: Low C: Medium | Medium<br>Q: Low A: Low C: Low |

This biotope is recorded in full salinity habitats (Connor *et al*., 2004). Little evidence was found for salinity tolerances > 40 ppt (an increase at the pressure benchmark). The photosynthetic rates of *Dictyopteris membranacea* decrease after short-term exposure (30 minutes) to salinities above 55 ppt (Gessner, 1969). Respiratory rates are more sensitive and decreased sharply after 30 minute exposures to salinities above 20 ppt (Gessner, 1969). Rietema (1993) examined ecotypic differences between North Sea and Baltic populations of *Delesseria sanguinea*. Optimal growth occurred in Baltic specimens at 19 -23 psu and North Sea specimens at 33 psu. Optimal photosynthesis occurred at full salinity, even in specimens collected from 15 psu (Lehnberg, 1978; cited in Lobban & Harrison, 1997). Increased salinity at 40 psu drastically reduced photosynthesis in Baltic specimens (Kinne, 1971b).

No evidence concerning the specific tolerance of the grazer *Echinus esculentus* was found. Although Reid (1935) described its range as between 33.5 on the Norwegian Coast to 36.0 at Finisterre. Echinoderm larvae have a narrow range of salinity tolerance and develop abnormally and die if exposed to reduced or increased salinity. In general echinoderms are considered to be stenohaline

species (Stickle & Diel, 1987) although acclimation to euryhaline conditions with periodic hyposalinity has been observed in some species (Russell, 2013).

**Sensitivity assessment.** Little evidence was found to assess the tolerance of the characterizing brown and red algae to hypersalinity at the pressure benchmark. Although some increases in salinity may be tolerated by the associated species present, this biotope is considered to be sensitive to a persistent increase in salinity to > 40 ppt (based on *Delesseria sanguinea*, *Dictyopteris membranacea* and *Echinus esculentus*). Biotope resistance is therefore assessed as 'Low' and recovery as 'Medium' (following restoration of usual salinity). Sensitivity is therefore assessed as 'Medium'.

| | | | |
|---|---|---|---|
| **Salinity decrease (local)** | Low<br>Q: High A: Low C: Medium | Medium<br>Q: High A: Low C: Medium | Medium<br>Q: High A: Low C: Medium |

This biotope is recorded in full salinity habitats (Connor *et al*., 2004). Salinity tolerances vary between species. The red algae *Cryptopleura ramosa*,occur in variable salinity on tide-swept biotopes (IR.MIR.KT.FilRVS) and would probably survive a reduction in salinity at the pressure benchmark (18-30 ppt). However other species within the biotope are likely to be more sensitive and a change at the pressure benchmark is considered likely to reduce species richness and result in the loss of characterizing species. Available evidence for sensitivities is described below.

The photosynthetic and respiratory rates of *Dictyopteris membranacea* fall sharply after short-term exposure (30 minutes) to salinities below 20 ppt (Gessner, 1969). Even short-term exposure (1 minute) to freshwater will irreversibly destroy the photosynthetic capability of *Dictyopteris membranacea*. This intolerance to low salinities is the factor confining this species to subtidal habitats (Gessner, 1969).

At low salinities photosynthesis in adult *Delesseria sanguinea* occurs in a restricted temperature range, although juvenile thalli photosynthesise across a wider range of temperatures (Lehnberg, 1978; cited in Lobban & Harrison, 1997). Rietema (1993) examined ecotypic differences between North Sea and Baltic populations of *Delesseria sanguinea*. Optimal growth occurred in Baltic specimens at 19 -23 psu and North Sea specimens at 33 psu. North Sea specimens died at 7.5 - 11 psu. *Delesseria sanguinea* is likely to tolerate reduced salinity at the pressure benchmark, although growth and reproduction may be reduced in low salinity environments when compared to full salinity.

A comparative study of salinity tolerances of macroalgae collected from North Zealand in the South Kattegat (Denmark) where salinity is 16 psu. Showed that species generally had a high tolerance (maintained more than half of photosynthetic capacity) to short-term exposure (4 days) to salinities lower than 3.7 (Larsen & Sand-Jensen, 2006). Tolerances varied between species; *Brongniartella byssoides* and *Delesseria sanguinea* were among the least tolerant species tested (Larsen & Sand-Jensen, 2006). However, it should be noted that the test salinities far exceed the pressure benchmark.

Edyvean & Ford (1984b) suggest that populations of the crustose coralline *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in tide pools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than

asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

No evidence concerning the specific tolerance of *Echinus esculentus* was found, although Reid (1935) described its range as between 33.5 on the Norwegian Coast to 36.0 at Finisterre, Norway. Echinoderm larvae have a narrow range of salinity tolerance and develop abnormally and die if exposed to reduced or increased salinity (Russell, 2013). In general echinoderms are considered to be stenohaline species (Stickle & Diel, 1987) although acclimation to euryhaline conditions with periodic hyposalinity has been observed in some species (Russell, 2013). Populations in the sublittoral fringe probably encounter reduced salinity due to low water and freshwater runoff or heavy rain and may tolerate low salinity for short periods.

**Sensitivity assessment.** The available evidence illustrates that responses to this pressure will vary between species and that a change at the pressure benchmark is likely to alter the composition of the red algal turf that characterizes the biotope and may alter the biomass and density of more tolerant species. Resistance is therefore assessed as 'Low' (loss of 25-75% of individuals). Resilience (following the removal of this pressure) is assessed as 'Medium' (2-10 years) based on loss of characterizing coralline crusts and sensitivity is therefore assessed as 'Medium'.

| | | | |
|---|---|---|---|
| **Water flow (tidal current) changes (local)** | High<br>Q: High A: Low C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Low C: High |

This biotope occurs across a range of flow speeds, from moderately strong (0.5-1.5 m/s) to areas where water flow is below 0.5 m/s (Connor *et al*., 2004). As water velocity increases foliose macroalgae can flex and reconfigure to reduce the size of the alga when aligned with the direction of flow, this minimises drag and hence the risk of dislodgement (Boller & Carrington, 2007). These characteristics allow these species to persist in areas that experience a range of flow speeds. Biogenic habitat structures, including the fronds of algae, reduce the effects of water flows on individuals by slowing and disrupting flow. Boller and Carrington (2006) found that the canopy created by a turf of *Chondrus crispus* reduced drag forces on individual plants by 15-65%. The compact, turf forming growth of the algal species characterizing this biotope will therefore reduce water flow and the risk of displacement through turbulence and friction.

The coralline crusts characterizing this biotope are securely attached and as these are flat are subject to little or no drag. Colonies of *Lithophyllum incrustans* appear to thrive in conditions exposed to strong water movement. Irvine & Chamberlain (1994). The suspension feeders within the biotope will also benefit from high water flows bringing food.

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by *Echinus esculentus* (Tillin & Tyler-Walters, 2014). The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. *Echinus esculentus* was recorded in biotopes from very weak (negligible) to moderately strong (0.5-1.5m/s) tidal streams, predominately in rock, mixed or very coarse sediment. *Echinus esculentus* move up the shore towards shallower waters when displaced, which is probably an adaptation to displacement to deeper waters by wave action (Lewis & Nichols, 1979a).Therefore, increased water flow is unlikely to kill individuals but may displace the population. However, once prior conditions return, the species would probably migrate back from the surrounding area.

Scour is a factor structuring this biotope in some areas and the species present are relatively scour

tolerant (Connor *et al*., 2004). Changes in the flow may increase or decrease sediment transport and associated scour. Changes at the pressure benchmark are only likely to affect examples of this biotope that occur in sheltered areas with lower levels of water movement. Reductions in flow in areas where currents are weak may lead to increased deposition of silts and alter the character of the biotope, whereas an increase in water flow at the pressure benchmark may re-suspend and remove sand particles which are less cohesive than mud particles. The level of impact will depend on site specific hydrodynamic and sediment conditions. Some periodic movement of sediments and changes in coverage is part of the natural temporal variation. At the level of the pressure benchmark a change in water flow is considered unlikely to affect the habitat.

**Sensitivity assessment.** As the biotope can occur in a range of flow speeds, resistance of the biotope to changes in water flow is assessed as 'High' and resilience as 'High' (by default) so that the biotope is assessed as 'Not sensitive'.

| | | | |
|---|---|---|---|
| **Emergence regime changes** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Changes in emergence are not relevant to this biotope (group) which is restricted to fully subtidal habitats.

| | | | |
|---|---|---|---|
| **Wave exposure changes (local)** | High<br>Q: High A: Low C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Low C: High |

This biotope is recorded from locations that are judged to range from moderately exposed to exposed (Connor *et al*., 2004), while Dommasnes (1969) recorded turfs from very wave sheltered areas in Norway. The degree of wave exposure influences wave height, i.e. more exposed areas with a longer fetch waves would be predicted to be higher. As this biotope occurs across a range of exposures, this was therefore considered to indicate, by proxy, that biotopes in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark. As water movement from wave action increases foliose macroalgae can flex and reconfigure to reduce the size of the alga when aligned with the direction of flow, this minimises drag and hence the risk of dislodgement (Boller & Carrington, 2007). These characteristics allow these species to persist in areas that experience a range of flow speeds resulting from wave action. The crustose corallines associated with this biotope have a flat growth form and are unlikely to be dislodged by increased wave action. Colonies of *Lithophyllum incrustans* appear to thrive in conditions exposed to strong water movement (Irvine & Chamberlain,1994).

A decrease in wave exposure at the pressure benchmark is unlikely to affect the brown and red algae directly. Decreases greater than the pressure benchmark that lead to reductions in boulder instability, abrasion and scour may lead to changes in the assemblage as species more characteristic of areas with less wave exposure are likely to colonize.

The available evidence suggests that associated species, including grazers occur across a range of wave exposures and are unlikely to be affected by a change in wave exposure at the pressure benchmark. Areas with high water velocities provide food to suspension feeders within the biotope such as sponges and anemones. *Echinus esculentus* can also occur within a range of wave exposure categories (Tillin & Tyler-Walters, 2014). An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this species. *Echinus esculentus* exhibit positive geotaxis and move up the shore

towards shallower waters when displaced, which is probably adaptation to displacement to deeper waters by wave action (Lewis & Nichols, 1979a).

**Sensitivity assessment.** The biotope is found across a range of wave exposures, mid-range populations are considered to have 'High' resistance to a change in significant wave height at the pressure benchmark. Resilience is assessed as 'High', by default, and the biotope is considered 'Not sensitive'.

## Chemical Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Transition elements & organo-metal contamination** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

This pressure is **Not assessed** but evidence is presented where available.

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. No information was found concerning the effects of heavy metals on turf forming and encrusting coralline algae. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg> inorganic Hg > Cu > Ag > Zn> Cd> Pb. Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. The sub-lethal effects of Hg (organic and inorganic) on the sporelings of an intertidal red algae, *Plumaria elegans*, were reported by Boney (1971). 100% growth inhibition was caused by 1 ppm Hg.

Uptake of heavy metals from solution by seaweed is influenced by factors such as light, algal nitrogen content, frond age, length of emersion, temperature, salinity, season of the year and presence of other pollutants in the surrounding water (see Lobban & Harrison, 1997) and consequently seaweeds may not accurately reflect metal concentrations in the surrounding water. The order of metal toxicity to algae varies with the algal species and the experimental conditions, but generally the order is Hg> Cu> Cd> Ag> Pb> Zn (Rice *et al*., 1973; Rai *et al*., 1981), however insufficient information was available to comment further on the particular intolerance of algal species within the biotope. Kinne (1984) reported developmental disturbances in *Echinus esculentus* exposed to waters containing 25 µg / l of copper (Cu) and reduced species viability would result in the long-term as the species fail to successfully recruit. The information available is patchy but there would appear to be some intolerance of species within the biotope to heavy metals.

| | | | |
|---|---|---|---|
| **Hydrocarbon & PAH contamination** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

This pressure is **Not assessed** but evidence is presented where available.

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Smith (1968) reported that oil and detergent dispersants from the *Torrey Canyon* spill affected high water plans of *Corallina officinalis* more than low shore plants and some plants were protected in deep pools. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith, 1968). Regrowth of fronds had begun within two months after spraying ceased (Smith, 1968). O'Brien &

Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also reported that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentrations of detergent. However, Smith (1968) reported that red algae such as *Chondrus crispus*, *Mastocarpus stellatus* and *Laurencia pinnatifida* were amongst the algae least affected by detergents. Laboratory studies by Grandy (1984) on the effects of oil and dispersants on several red algal species concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages.

Cole *et al*. (1999) suggested that herbicides were (not surprisingly) very toxic to algae and macrophytes. Hoare & Hiscock (1974) noted that with the exception of *Phyllophora* species, all red algae including encrusting coralline forms were excluded from the vicinity of an acidified halogenated effluent discharge in Amlwch Bay, Anglesey and intertidal populations of *Corallina officinalis* occurred in significant amounts only 600 m east of the effluent. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

O'Brien & Dixon (1976) report that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentrations. Smith (1968) reported that 10 ppm of the oil dispersive detergent BP 1002 killed the majority of specimens in 24 hrs in toxicity tests. However, the effects take several days to manifest; when killed the algae turn bright orange. Smith (1968) also demonstrated that 0.5 -1 ppm of the detergent BP1002 resulted in developmental abnormalities in echinopluteus larvae of *Echinus esculentus*. *Echinus esculentus* populations in the vicinity of an oil terminal in La Coruna Bay, Spain, showed developmental abnormalities in the skeleton. Hoare & Hiscock (1974) reported that red algae (e.g. *Lithothamnia* spp., *Corallina officinalis*, *Polyides rotunda*, *Dilsea carnosa*, *Rhodymenia palmata* and *Desmarestia aculeata*), echinoderms, Polyzoa and amphipod crustaceans appeared to be particularly intolerant of the reduction in water quality associated with the effluent discharged (containing free halogens, HCL & $H_2SO_4$) from a bromine extraction works into Amlwch Bay, Anglesey. Red algal species and the urchin *Echinus esculentus* are likely to be affected by synthetic chemicals.

Heavy mortality of *Delesseria sanguinea* occurred down to 12 m after the *Torrey Canyon* oil spill, although it was unclear how much of the effect was due to oil rather than dispersant contamination. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Delesseria sanguinea* (Grandy, 1984; cited in Holt et al., 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. Holt *et al*. (1995) concluded that *Delesseria sanguinea* is probably generally sensitive to chemical contamination.

Most pesticides and herbicides were suggested to be very toxic for invertebrates, especially crustaceans (amphipods isopods, mysids, shrimp and crabs) and fish (Cole *et al*., 1999).

| | | | |
|---|---|---|---|
| **Synthetic compound contamination** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

This pressure is **Not assessed** but evidence is presented where available.

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Smith (1968) reported that oil and detergent dispersants from the *Torrey Canyon* spill affected high water plans of *Corallina officinalis* more than low shore plants and some plants were protected in deep pools. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith, 1968). Regrowth of fronds had begun within two months after spraying ceased (Smith, 1968). O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also reported that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentration of detergent. However, Smith (1968) reported that red algae such as *Chondrus crispus*, *Mastocarpus stellatus* and *Laurencia pinnatifida* were amongst the algae least affected by detergents. Laboratory studies by Grandy (1984) on the effects of oil and dispersants on several red algal species concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages.

Cole *et al*. (1999) suggested that herbicides were (not surprisingly) very toxic to algae and macrophytes. Hoare & Hiscock (1974) noted that with the exception of *Phyllophora* species, all red algae including *Delesseria sanguinea* and encrusting coralline forms were excluded from the vicinity of an acidified halogenated effluent discharge in Amlwch Bay, Anglesey and intertidal populations of *Corallina officinalis* were abundant only 600m east of the effluent. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. Heavy mortality of *Delesseria sanguinea* occurred down to 12 m after the *Torrey Canyon* oil spill (probably due to a mixture of wave action and dispersant application). Laboratory studies of the effects of oil and dispersants on several red algae species, including *Delesseria sanguinea* (Grandy, 1984; cited in Holt *et al*., 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages.

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Most pesticides and herbicides were suggested to be very toxic for invertebrates, especially crustaceans (amphipods isopods, mysids, shrimp and crabs) and fish (Cole *et al*., 1999).

| | | | |
|---|---|---|---|
| **Radionuclide contamination** | No evidence (NEv)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

No evidence.

| | | | |
|---|---|---|---|
| **Introduction of other substances** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

This pressure is **Not assessed**.

| | | | |
|---|---|---|---|
| **De-oxygenation** | No evidence (NEv)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

The effects of reduced oxygenation on algae are not well studied. Plants require oxygen for respiration, but this may be provided by production of oxygen during periods of photosynthesis. Lack of oxygen may impair both respiration and photosynthesis (see review by Vidaver, 1972). A study of the effects of anoxia on the red alga, *Delesseria sanguinea*, revealed that specimens died after 24 hours at 15°C but that some survived at 5°C (Hammer, 1972).

No evidence is available to make a resistance assessment for the key characterizing species.Specific information concerning oxygen consumption and reduced oxygen tolerances were not found for the key characterizing species within the biotope. This pressure is not assessed due to lack of evidence.

| | | | |
|---|---|---|---|
| **Nutrient enrichment** | High<br>Q: High A: Low C: High | High<br>Q: High A: High C: Medium | Not sensitive<br>Q: High A: Low C: Medium |

Over geological timescales periods of increased nutrient availability have experienced increases in the distribution of crustose coralline species at the expense of corals (Littler & Littler, 2013), suggesting that this group have some tolerance for enhanced nutrient levels. Overall, Littler & Littler (2013) suggested that corallines as a group can tolerate both low and elevated levels of nutrients. The crustose coralline *Lithophyllum incrustans* was present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of nutrient enrichment from domestic sewage (Arévalo *et al*., 2007). Increased eutrophication of the Skagerrak strait has been linked to an increase in abundance of the characterizing species *Phycodrys rubens*. Increases in this species have also been observed with local eutrophication in shallow bays in the Baltic (Pedersén & Snoeijs 2001), suggesting this species is tolerant of some enrichment. An increase in abundance of red algae, including *Delesseria sanguinea*, was associated with eutrophication in the Skagerrak area, Sweden, especially in areas with the most wave exposure or water exchange (Johansson *et al*., 1998). However, where eutrophication resulted in high siltation rates, the delicate foliose red algae such as *Delesseria sanguinea* were replaced by tougher, erect red algae (Johansson *et al*., 1998). The brown alga *Dictyopteris membranacea* was formerly very abundant in the Lagoon of Venice but was replaced by *Ulva rigida* when levels of organic and inorganic pollution increased (Sfriso *et al*., 1992). This species like *Cystoseira* spp. requires, and is therefore indicative of high water quality.

Grazers in the biotope may benefit from increased availability of food resources, due to enhanced growth, and high levels of grazing may reduce the effects of eutrophication. Atalah & Crowe (2010) added nutrients to rockpools in controlled experiments. The rockpools were occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. The invertebrates present

were mostly *Patella ulyssiponensis*, the winkle *Littorina littorea* and the flat top shell *Gibbula umbilicalis*. Nitrogen and phosphorous enhancement was via the addition of fertilisers, as either 40 g/litre or 20 g/litre. The treatments were applied for seven months and experimental conditions were maintained every two weeks. A grazer and nutrient addition treatments was also applied where grazers were removed manually from pools and a 1 m strip bordering the pools. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. In the pools the chronic addition of nutrients had no significant effect on the cover of crustose coralline algae or the red turfing algae. There was a significant interactive effect of grazing and nutrients however on the cover of crustose coralline algae. Pair-wise comparisons showed that cover of crustose coralline algae was significantly reduced where nutrients were added only under reduced grazing conditions, with an absolute decrease of 44 % (±8.0 S.E.) relative to the controls (P<,0.05). Grazers limit the effects of nutrient enrichment and in the absence of grazers significant changes in the structure of the algal assemblage from competition with green alga could emerge following eutrophication. However, the high levels of scour and abrasion in this biotope would prevent permanent colonization by larger perennial species and the ephemeral algae would be likely to be displaced by space-occupying red algae following disturbance and the creation of physical gaps in the habitat.

**Sensitivity assessment**. The pressure benchmark is relatively protective and may represent a reduced level of nutrient enrichment in previously polluted areas and may limit the growth of ephemeral green algae. Due to the tolerance of high levels of nutrient input demonstrated generally by encrusting corallines and red algal turfs, e.g. Belgrove *et al*., (2010) and Atalah & Crowe, (2010), resistance to this pressure is assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

| | | | |
|---|---|---|---|
| **Organic enrichment** | High<br>Q: High A: Medium C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Medium C: High |

As the biotope occurs in tide swept or wave exposed areas (Connor *et al*., 2004), water movements will disperse organic matter reducing the level of exposure. The crusting coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean that were exposed to high levels of organic pollution from domestic sewage (Arévalo *et al*., 2007). As turfs of red algae can trap large amounts of sediment the red algae are not considered sensitive to the sedimentation element of this pressure. Within trapped sediments associated species and deposit feeders would be able to consume inputs of organic matter.

The animals found within the biotope may be able to utilise the input of organic matter as food, or are likely to be tolerant of inputs at the benchmark level. Lawrence (1975) reported that sea urchins had persisted over 13 years on barren grounds near sewage outfalls, presumably feeding on dissolved organic material, detritus, plankton and microalgae, although individuals died at an early age. The ability to absorb dissolved organic material was suggested by Comely & Ansell (1988).

**Sensitivity assessment**. Based on resistance to sedimentation, exposure to wave action, and the dominance of red algal turfs in areas subject to sewage inputs, resistance is assessed as 'High' and resilience as 'High' (by default). The biotope is, therefore, considered to be 'Not sensitive' to this pressure at the benchmark.

## A Physical Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Physical loss (to land or freshwater habitat)** | None<br>Q: High A: High C: High | Very Low<br>Q: High A: High C: High | High<br>Q: High A: High C: High |

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is therefore 'High'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

| | | | |
|---|---|---|---|
| **Physical change (to another seabed type)** | Low<br>Q: High A: High C: High | Very Low<br>Q: High A: Low C: High | High<br>Q: High A: Low C: High |

The loss of hard substratum would remove the rock habitat; sediments would be unsuitable for the attached brown and red algae that characterize this biotope and the associated epifauna such as *Alcyonium digitatum* and *Caryophyllia smithii* that characterize this biotope.

Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial hard substratum may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al*., 2012; Firth *et al*., 2013) or the presence of non-native species (Bulleri & Airoldi, 2005). Many species have specific preferences for substratum type. *Corallina officinalis* shows optimal settlement on fine particle artificial substrata (0.5 - 1 mm surface particle diameter). Although spores will settle and develop as crustose bases on smooth surfaces, fronds were only initiated on rough surfaces. *Corallina officinalis* settled on artificial substrata within one week placement during the summer months in New England (Harlin & Lindbergh 1977). However, in the laboratory only fronds grew from bases attached to smooth surfaces (Wiedeman pers comm. Previous MarLIN review). Tests with stone panels fixed to the sublittoral, mid-tide and high-tide levels of varying roughness found that *Ulva* species settle preferentially on smoother, fine grained substratum (chalk, mottled sandstone) and *Porphyra purpurea* on rougher, granulated substratum (limestone, granite, basaltic larvae) (Luther, 1976) indicating species specific optimal habitats.

**Sensitivity assessment**. Based on the loss of suitable habitat, resistance is assessed as 'None' recovery is assessed as 'Very Low' as the change at the pressure benchmark is permanent. Sensitivity is therefore 'High'.

| | | | |
|---|---|---|---|
| **Physical change (to another sediment type)** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Not relevant to biotopes occurring on bedrock.

| | | | |
|---|---|---|---|
| **Habitat structure changes - removal of substratum (extraction)** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

The species characterizing this biotope are epifauna or epiflora occurring on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

| | | | |
|---|---|---|---|
| **Abrasion/disturbance of the surface of the substratum or seabed** | Medium | High | Low |
| | Q: High A: Low C: Medium | Q: High A: Low C: Medium | Q: High A: Low C: Medium |

The species characterizing this biotope occur on the rock and therefore have no protection from abrasion at the surface. No direct evidence was found to assess this pressure and evidence from intertidal studies on trampling on algal turfs has been used as a proxy. In general, studies show that turf forming algae appear to be relatively resistant to single events and low levels of trampling. Brosnan & Crumrine (1994), for example, found that in experimentally trampled plots the cover of foliose and canopy forming species declined while turf forming algae were relatively resistant. Similarly, a comparison of rocky intertidal ledges that received different amounts of visitors in Dorset, England, found that *Corallina officinalis* and encrusting corallines were present on both heavily visited and less visited ledges suggesting that these species has some resistance to trampling (Pinn & Rodgers, 2005). Fletcher and Frid (1996a; 1996b) noted a decrease in the understorey algal community of encrusting coralline algae and red algae, which was probably an indirect effect due to increased desiccation after removal of the normally protective fucoid canopy (Hawkins & Harkin, 1985) by trampling.

Schiel & Taylor (1999) reported the death of encrusting corallines one month after trampling due to removal of their protective canopy of fucoids by trampling (10 -200 tramples where one trample equals one transect walked by one person). A higher proportion of corallines died back in spring treatments presumably due to the higher levels of desiccation stress expected at this time of year. However, encrusting corallines increased within the following year and cover returned to control levels within 21 months (Schiel & Taylor, 1999). Mechanical abrasion from scuba divers was also reported to impact encrusting corallines, with cover of *Lithophyllum stictaeforme* greater in areas where diving was forbidden than visited areas (abundance, 6.36 vs 1.4; it is presumed this refers to proportion of cover, although this is not clear from the text, Guarinieri *et al*., 2012).

Dethier (1994) experimentally manipulated surface abrasion on a range of encrusting algae including *Lithophyllum impressum*. Crusts were brushed once each month for 1 minute, over 24 months with either a nylon or steel brush. Unbrushed controls grew by approximately 50 % whereas the cover of nylon and steel brushed crusts decreased by approximately 25% and 40% respectively (interpreted from figures in Dethier, 1994). In laboratory tests on three samples of *Lithophyllum impressum* chips, brushing with a steel brush for 1 minute once a week for 3 weeks, resulted in no cover loss of two samples while a third 'thinned and declined' (Dethier, 1994).

MacDonald *et al*., (1996) assessed benthic species sensitivity to fishing disturbance by 'scoring' each species ability to withstand the physical impact of a single fishing disturbance and recovery potential assuming no further fishing disturbance occurred. These authors classified the slow growing epifaunal species *Echinus esculentus* as being 'very fragile' and having 'moderate' recovery potential, based on life history characteristics. Kaiser *et al*. (2000) reported that *Echinus esculentus* were less abundant in areas subject to high trawling disturbance in the Irish Sea. This species was reported to suffer badly as a result of impact with passing scallop or queen scallop dredges (Bradshaw *et al*. 2000; Hall-Spencer & Moore, 2000a).

**Sensitivity assessment**. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on evidence from intertidal step experiments and the relative robustness of encrusting corallines, *Corallina officinalis* turf and associated species, resistance, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance and resilience will be lower (and hence sensitivity greater) to abrasion events

that exert a greater crushing force and remove the bases than the trampling examples the assessment is based on). Resistance is therefore assessed as 'Low' and recovery as 'Medium' so that the sensitivity of the biotope defined by this species is assessed as 'Medium'. Based on epifaunal position, size and fragility and the available evidence, *Echinus esculentus* is assessed as having 'Low' resistance to abrasion. Resilience is assessed as 'High' and therefore sensitivity is assessed as 'Low'.

| | | | |
|---|---|---|---|
| **Penetration or disturbance of the substratum subsurface** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

The species characterizing this biotope group are epifauna or epiflora occurring on rock which is resistant to subsurface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure.

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|---|---|---|---|
| **Changes in suspended solids (water clarity)** | Low<br>Q: High A: Low C: NR | Medium<br>Q: High A: Low C: Medium | Medium<br>Q: High A: Low C: Medium |

In areas of high turbidity the brown seaweeds are replaced by red algae that are more tolerant of lower light levels and increased scour. Red algae possess only trace amounts of chlorophyll *a* (Lüning & Schmitz, 1988). Their main photosynthetic pigments are phycobiliproteins, which absorb optimally in the green light of deeper coastal waters. Photosynthesis in *Delesseria sanguinea* is inhibited by high light levels >200 µmol/m□/s, roughly equivalent to very clear shallow water in summer (Kain & Norton, 1990). However, in turbid coastal waters, where green light prevails, photosynthetic effectiveness increases with depth in red algae rich in phycoerythrin such as *Delesseria sanguinea* (Lüning, 1990). *Delesseria sanguinea* can grow in darkness using energy reserves stored in the stipe or lower regions of the frond ribs (Lüning, 1990). Increased turbidity would decrease the light levels at depth and may reduce the effective day length and induce reproduction earlier than in less turbid areas (Kain & Norton, 1990). *Delesseria sanguinea* is adapted to grow at depth or in the shade of other plants. Long-term (years) decreased turbidity may restrict its extent to shallower waters. Short-term changes may affect growth and reproduction, however, as a perennial, the adults will probably survive.

A decrease in turbidity that also resulted in a reduction in scour may allow kelp biotopes to extend in depth and replace this biotope. However, where significant scour still occurred from, for example periodic remobilisation of sand, then the biotope may not change in character.

**Sensitivity assessment.** This biotope is characterized by the presence of brown algae and may revert to a red algae only biotope in areas of high turbidity, such as the similar biotope IR.MIR.KR.XFoR, which is dominated by red seaweeds tolerant of turbidity including *Plocamium cartilagineum* and *Calliblepharis ciliata* (which may also be found in this biotope). The fauna in such biotopes is less diverse and at lower abundances (Connor *et al*., 2004). No information was found for suspended solid thresholds at which the brown seaweeds may be replaced and whether the brown algae could survive, with reduced growth, at the pressure benchmark. Resistance to an increase at the pressure benchmark is assessed as 'Low' and resilience (following a return to previous habitat conditions) is assessed as 'Medium', as red algal turfs may prevent recolonization by brown algae until physical gaps are formed. Sensitivity is therefore assessed as 'Medium'. This biotope is considered to be 'Not sensitive' to a change in suspended solids, where levels of scour are unaffected.

A reduction in scour may allow less scour tolerant species and those adapted to higher light levels, such as kelps, to colonize the biotope. Resistance to a decrease in suspended solids, accompanied by a significant reduction in scour is assessed as 'Medium' as space pre-emption by red algae is likely to prevent colonization over the course of a year. Resilience (following a return to previous habitat conditions) is assessed as 'High'. Sensitivity is therefore assessed as 'Low'.

| | | | |
|---|---|---|---|
| **Smothering and siltation rate changes (light)** | High<br>Q: Low A: NR C: NR | High<br>Q: High A: High C: High | Not sensitive<br>Q: Low A: Low C: Low |

Increased abundance of algal turfs worldwide has been linked to sediment perturbations although not all the pathways and mechanisms of these effects are clear (see review by Airoldi, 2003). However, even the most tolerant of organisms would eventually suffer from inhibition and mortality following smothering although the thresholds for these effects have has not been identified (Airoldi, 2003).

Airoldi (2003) identified a number of morphological, physiological and life history traits that conferred high levels of tolerance to sedimentation. Those shared by characterizing species in the biotope are the regeneration of upright fronds from a perennial basal crust resistant to burial and scour, calcified thalli, apical meristems, large reproductive ouptuts, lateral vegetative growth and slow growth rates (Airoldi, 2003). Algae with tough thalli are more resistant to sedimentation and scour (Pedersén & Snoeijs, 2001).

In a review of the effects of sedimentation on rocky coast assemblages, Airoldi (2003) outlined the evidence for the sensitivity of encrusting coralline algae to sedimentation. The reported results are contradictory with some authors suggesting that coralline algae are negatively affected by sediments while others report that encrusting corallines are often abundant or even dominant in a variety of sediment impacted habitats (Airoldi, 2003 and references therein). Crustose corallines have been reported to survive under a turf of filamentous algae and sediment for 58 days (experiment duration) in the Galapagos (species not identified, Kendrick, 1991). The crustose coralline *Hydrolithon reinboldii*, has also been reported to survive deposition of silty sediments on subtidal reefs off Hawaii (Littler, 1973).

In an experimental study, Balata *et al*. (2007) enhanced sedimentation on experimental plots in the Mediterranean (close to Tuscany) by adding 400 g of fine sediment every 45 days on plots of 400 $cm^2$ for 1 year. Nearby sites with higher and lower levels of sedimentation were assessed as control plots. Some clear trends were observed. *Dictyota dichotoma* was more abundant at sites with lower sedimentation (mean 2 and 6% of cover) and present in lower abundances (<1 %) at sites where sediments were added and at sites with naturally high sediment loads (Balata *et al*., 2007). Foliose algae, in general, were present in much greater abundances in areas with low sedimentation (mean cover of approximately 13% and 19%) and much reduced at experimental sites and those with high natural sedimentation (mean cover of approximately 2-3 %). Crustose corallines declined at medium and high levels of sedimentation but were still major space occupiers (100% cover). Some species of filamentous algae increased where sediment loads were naturally high or experimentally enhanced (Balata *et al*., 2007). The experiment relates to chronic low levels of sedimentation rather than a single acute event, as in the pressure benchmark, however the trends observed are considered to have some relevance to the pressure assessment. Foliose algae within the biotope are likely to be more sensitive to sedimentation than the characterizing encrusting corallines; however the presence of the foliose algae, including *Dictyota dichotoma* in sand scoured biotopes suggests some tolerance of sedimentation and

associated scour.

Cooke (1957, cited in Cranmer, 1985) stated that echinoids 'dislike mud', possibly because of fine substratum affecting their respiratory capability (Dyer *et al*., 1983). However, the associated urchin species *Echinus esculentus* is likely to be able to tolerate small quantities of sediment deposition (MES, 2010). Comely and Ansell (1988) recorded large *Echinus esculentus* from kelp beds on the west coast of Scotland in which the substratum was seasonally covered with 'high levels' of silt. Last *et al*. (2011) found that a smaller epifaunal urchin *Psammechinus miliaris* is moderately tolerant of shorter term (12 days) burial events, with less than 25 % mortality of all buried specimens. Survivorship was partly due to the re-emergence of many specimens, even from depths of up to7 cm, particularly when buried under coarse sediment. After 12 days of burial, mortality in the specimens that remained buried was high. Percentage mortality increased with progressively finer sediment fractions.

**Sensitivity assessment.** Based on the biotope exposure to wave and water flow which will remobilise sediments and remove these, biotope resistance to this pressure, at the benchmark, is assessed as 'High', resilience is assessed as 'High' (by default) and the biotope is considered to be 'Not sensitive'. This is a likely result of the growth form of the characterizing foliose red algae and their presence in biotopes subject to sedimentation and scour (including the assessed biotope). The assessment considers that sediments are rapidly removed from the biotope and that the scour tolerance of the red algae and other species would prevent significant mortalities although some damage and abrasion may occur. However, if the deposit remained in place; i.e. due to the scale of the pressure or where biotopes were sheltered, or only seasonally subject to water movements or where water flows and wave action were reduced e.g. by the presence of tidal barrages, then resistance would be lower and sensitivity would be greater.

| | | | |
|---|---|---|---|
| **Smothering and siltation rate changes (heavy)** | Low<br>Q: High A: Low C: Medium | High<br>Q: Low A: NR C: NR | Low<br>Q: Low A: Low C: Low |

The available evidence for siltation pressures is outlined for the 'light' deposition pressure. At the pressure benchmark 'heavy deposition' represents a considerable thickness of deposit. Complete burial of algal turf and encrusting corallines and associated animals would occur. Removal of the sediments by wave action and tidal currents would result in considerable scour. The effect of this pressure will be mediated by the length of exposure to the deposit.

No evidence was found for the length of time *Echinus esculentus* could survive being buried under 30cm of sediment. In areas of high water flow, dispersion of fine sediments may be rapid and this will mitigate the magnitude of this pressure by reducing the time exposed and the depth of over burden that the species must crawl through.

**Sensitivity assessment.** Resistance is assessed as 'Medium-Low' as the impact on the characterizing and associated red algal species could be significant but may be mitigated by rapid removal. Resilience is assessed as 'High' based on vegetative re-growth from the scour-tolerant surviving bases of the characterizing species. Biotope sensitivity is therefore assessed as 'Low'. Resistance of *Echinus esculentus* to this pressure was assessed as 'None' by Tillin & Tyler-Walters (2014) due to the depth of overburden and the predicted low level of vertical migration. Resilience was assessed as 'Medium' (2-10 years) and sensitivity is therefore assessed as 'Medium'. Sensitivity may be lower where the footprint of the deposit is small and migration of adults into the habitat from adjacent populations results in rapid recovery. The biotope assessment is based on the red algae, rather than *Echinus esculentus*.

| | | | |
|---|---|---|---|
| **Litter** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

**Not assessed.**

| | | | |
|---|---|---|---|
| **Electromagnetic changes** | No evidence (NEv)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

No evidence.

| | | | |
|---|---|---|---|
| **Underwater noise changes** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Not relevant.

| | | | |
|---|---|---|---|
| **Introduction of light or shading** | High<br>Q: High A: Medium C: Medium | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Medium C: Medium |

The red algae are generally flexible in terms of light requirements and can acclimate to different levels of light intensity and quality. Red algae possess only trace amounts of chlorophyll *a* (Lüning & Schmitz, 1988). Their main photosynthetic pigments are phycobiliproteins, which absorb optimally in the green light of deeper coastal waters. Photosynthesis in *Delesseria sanguinea* is inhibited by high light levels >200 µmol/m/s, roughly equivalent to very clear shallow water in summer (Kain & Norton, 1990). However, in turbid coastal waters, where green light prevails, photosynthetic effectiveness increases with depth in red algae rich in phycoerythrin such as *Delesseria sanguinea* (Lüning, 1990). *Delesseria sanguinea* can grow in darkness using energy reserves stored in the stipe or lower regions of the frond ribs (Lüning, 1990). Increased turbidity would decrease the light levels at depth and may reduce the effective day length and induce reproduction earlier than in less turbid areas (Kain & Norton, 1990). *Delesseria sanguinea* is adapted to grow at depth or in the shade of other plants. Long-term (years) decreased turbidity may restrict its extent to shallower waters. Short-term changes may affect growth and reproduction, however, as a perennial, the adults will probably survive.

Coralline crusts are shade tolerant algae, often occurring under a macroalgal canopy that reduces light penetration. Encrusting corallines can occur in deeper water than other algae where light penetration is limited. Samples of *Lithophyllum impressum* suspended from a raft and shaded (50-75 % light reduction) continued to grow over two years (Dethier, 1994). Similarly *Plocamium cartilagineum* grows in shaded conditions beneath laminarian canopies, where irradiance is greater growth is lower and it appears that light levels of 0.5 mmol/$m^2$/s are inhibitory (Kain, 1987). In areas of higher light levels, the fronds and bases may be lighter in colour due to bleaching (Colhart & Johansen, 1973). Other red algae in the biotope are flexible with regard to light levels and can also acclimate to different light levels.

**Sensitivity assessment.** As the key structuring and characterizing red algae species colonize a broad range of light environments from intertidal to deeper sub tidal and shaded understorey habitats the biotope is considered to have ‘High’ resistance and, by default, ‘High’ resilience and therefore is ‘Not sensitive’ to this pressure. The red algae are generally flexible in terms of light requirements and can acclimate to different levels of light intensity and quality. Coralline crusts

are shade tolerant algae, often occurring under a macroalgal canopy that reduces light penetration. Encrusting corallines can occur in deeper water than other algae where light penetration is limited. Samples of *Lithophyllum impressum* suspended from a raft and shaded (50-75 % light reduction) continued to grow over two years (Dethier, 1994). Similarly *Plocamium cartilagineum* grows in shaded conditions beneath laminarian canopies: where irradiance is greater, growth is lower and it appears that light levels of 0.5 mmol/$m^2$/s are inhibitory (Kain, 1987). In areas of higher light levels, the fronds and bases may be lighter in colour due to bleaching (Colhart & Johansen, 1973). Other red algae in the biotope are flexible with regard to light levels and can also acclimate to different light levels.

| | | | |
|---|---|---|---|
| **Barrier to species movement** | High<br>Q: NR A: NR C: NR | High<br>Q: High A: High C: High | Not sensitive<br>Q: Low A: Low C: Low |

Barriers that reduce the degree of tidal excursion may alter propagule supply to suitable habitats from source populations. Conversely the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. Barriers and changes in tidal excursion are not considered relevant to the characterizing algae as species dispersal is limited by the rapid rate of settlement. Resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'.

| | | | |
|---|---|---|---|
| **Death or injury by collision** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Not relevant' to seabed habitats. NB. Collision by grounding vessels is addressed under surface abrasion.

| | | | |
|---|---|---|---|
| **Visual disturbance** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Not relevant.

## Biological Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Genetic modification & translocation of indigenous species** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Key characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered 'Not relevant' to this biotope group.

| | | | |
|---|---|---|---|
| **Introduction or spread of invasive non-indigenous species** | High<br>Q: High A: Low C: Low | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: Low C: Low |

A number of invasive red algae have been recorded in the UK, from reported habitat preferences *Bonnemaisonia hamifera* does not appear to be present in scoured environments although the

harpoon weed, *Asparagopsis armata* is found in sandy pools (Guiry & Guiry, 2015). In North America *Grateloupia turuturu* is a major competitor of *Chondrus crispus*, although *Grateloupia turuturu* is present in the UK, this large foliose species may not be able to colonize this scoured biotope.

The invasive red algae *Lophocladia lallemandi*, that grows on *Dictyota dichotoma* in Mallorcan coastal waters, results in an increase in antioxidant biomarkers indicating stress and cellular damage that could lead to increased mortality (Tejada & Sureda, 2014). This species is not currently present in the UK but illustrates a potential effect on INIS on native species.

**Sensitivity assessment.** As scour within this biotope limits establishment of all but robust species, resistance to INIS is assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'.

| | | | |
|---|---|---|---|
| **Introduction of microbial pathogens** | High<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: High C: High |

No evidence was found that microbial pathogens cause high levels of disease or mortality in this biotope. Diseased encrusting corallines were first observed in the tropics in the early 1990's when the bacterial pathogen Coralline Lethal Orange Disease (CLOD) was discovered (Littler & Littler, 1995). All species of articulated and crustose species tested to date are easily infected by CLOD and it has been increasing in occurrence at sites where first observed and spreading through the tropics. Another bacterial pathogen causing a similar CLOD disease has been observed with a greater distribution and a black fungal pathogen first discovered in American Samoa has been dispersing (Littler & Littler, 1998). An unknown pathogen has also been reported to lead to white 'target-shaped' marks on corallines, again in the tropic (Littler *et a*l., 2007). No evidence was found that these are impacting temperate coralline habitats.

Extracts of some red algae show antimicrobial, antiviral or antifungal properties providing some protection from pathogens. For example, *Bonnemaisonia asparagoides* produces surface-bound antibacterial compounds with a significant impact on the abundance and composition of the associated bacterial community (Nylund *et al*., 2010). Extracts of *Dictyota dichotoma* have antibiotic properties (Hornsey & Hide, 1974) and antiviral properties (Rabanal *et al*., 2014).

It is likely that populations within this biotope suffer some low-levels of infection of microbial pathogens and parasites. Specific examples include the red algal hemiparasite *Gonimophyllum buffhamii*, which occurs occasionally on subtidal *Cryptopleura ramosa* on southern and western coasts (Guiry & Guiry, 2015). Comely & Ansell (1988) recorded 28 invertebrate species associated with *Echinus esculentus* from the west coast of Scotland near Oban. These included the parasites *Echinomermella grayi* and *Euonyx chelatus* mentioned above and additionally 4 species of commensal polychaetes, a copepod and 10 amphipod species. The polychaete *Adyte assimilis* and the copepod *Pseudoanthessius liber* were regular commensals amongst the spines. Hyman (1955) states that *Echinus esculentus* is often infested with parasitic copepods e.g. *Asterocheres echinola*. *Echinus esculentus* is susceptible to 'Bald-sea-urchin disease', which causes lesions, loss of spines, tube feet, pedicellariae, destruction of the upper layer of skeletal tissue and death. It is thought to be caused by the bacteria *Vibrio anguillarum* and *Aeromonas salmonicida*. Bald sea-urchin disease was recorded from *Echinus esculentus* on the Brittany Coast. Although associated with mass mortalities of *Strongylocentrotus franciscanus* in California and *Paracentrotus lividus* in the French Mediterranean it is not known if the disease induces mass mortality (Bower 1996). No evidence of mass mortalities of *Echinus esculentus* associated with disease have been recorded in the UK.

**Sensitivity assessment**. Based on the available evidence for the characterizing coralline crust, *red algae* and other associated species the biotope is judged to have 'High' resistance to this pressure as no significant mortalities have been recorded. By default resilience is assessed as 'High' and the biotope is classed as 'Not sensitive' at the pressure benchmark.

| | | | |
|---|---|---|---|
| **Removal of target species** | Low<br>Q: Low A: NR C: NR | Medium<br>Q: High A: Low C: Medium | Medium<br>Q: Low A: Low C: Low |

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. No commercial application or harvesting of encrusting corallines was described in the literature.

The key characterizing foliose red algal species are not commercially targeted but have been investigated as alternative sources of the phycocolloid substances alginates and agar (Mathieson *et al*., 1984; Maggs, 1990) and in the future may be subject to harvesting.

The urchin *Echinus esculentus* may be harvested commercially as souvenirs for the tourist trade, or for human consumption (Comely & Ansell, 1988). Nichols (1981, 1984) examined the Cornish sea urchin fishery. It was noted that most commercial divers were inefficient at collecting the sea urchin, as many were obscured by weeds and other debris, or undersides of rocks, so that commercial divers probably leave behind a 'fair proportion' of the population. Intensive collecting did remove all urchins down to 15m from part of Lamora Cove, Cornwall in 1978. But the subsequent diving survey in 1979, showed that the urchins had returned (although no abundance was given), due to migration from deeper waters (Nichols 1981; 1984). At the time of the study (ca 1978-1984) about 0.5 million sea-urchins (*Echinus*) were collected annually. Nichols (1984) concluded that the fishery was sustainable, based on the few years studied. However, he cautioned against complete clearance due to the adverse effects on habitats. Also natural fluctuations in *Echinus* populations meant that it was not possible to determine an acceptable level of catch. He advised that population densities should not be allowed to fall below 0.2/$m^2$, as this population density had been stable at Shallow Tinker Shoal, Plymouth for 24 years (Nichols 1984).

**Sensitivity assessment**. The species that are harvested, or potentially harvested, in this biotope are all attached or sedentary and relatively conspicuous. A single event of targeted harvesting could therefore efficiently remove individuals and resistance is assessed as 'Low'. This assessment is supported by evidence from Sharp *et al*., (1993) on the proportion of biomass of *Chondrus crispus* removed commercially as no specific information was available for characterizing species. Resilience of the red seaweeds is assessed as 'Medium' (based on some damage occurring to perennial holdfasts and bases although see caveats in the resilience section) and biotope sensitivity is assessed as 'Medium'. This assessment refers to a single collection event, long-term harvesting over wide spatial scales will lead to greater impacts, with lower resistance and longer recovery times. Commercial harvesting by divers of *Echinus esculentus* may be relatively inefficient, but at high intensities can remove 100% of the population (within the impacted area) resistance is assessed as 'Low' (significant mortality, 25-75% loss) and resilience is assessed as 'High'. Sensitivity is therefore considered to be 'Low'. The biotope sensitivity is based on the red seaweed assessment.

| | | | |
|---|---|---|---|
| **Removal of non-target species** | Low<br>Q: Low A: NR C: NR | Medium<br>Q: High A: High C: High | Medium<br>Q: Low A: Low C: Low |

Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by red and brown algae. The loss of these due to incidental removal as by-catch would alter the character of the biotope resulting in reclassification and result in the loss of species richness. The ecological services such as primary production and the habitat provided by these species would also be lost.

**Sensitivity assessment.** Removal of a large percentage of the characterizing species resulting in bare rock would alter the character of the biotope, species richness and ecosystem function. Resistance is therefore assessed as ‘Low’ and recovery as ‘Medium’ (based on removal of bases and holdfasts), so that biotope sensitivity is assessed as 'Low’.

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